Phasing out fossil gas steam generators: Demand-based generation of process steam from thermally stored renewable energy with the Rotating Drum Heat Exchanger

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Abstract

State-of-the-art two-tank molten salt storages utilize only the sensible heat storable in the liquid phase of nitrate salts. By extending the lower temperature limit into the solid state, the phase change enthalpy of the material can be utilized as well. This increases the storage density of nitrate salts up to 330 $KWh \cdot m^{-3}$, which is an increase of 60 % compared to current systems. The Rotating Drum Heat Exchanger recently developed by the authors is predestined for the transfer of both sensible and latent heat. Thereby, a horizontally mounted rotating drum is partially immersed in liquid nitrate salt. While water evaporates inside the drum, liquid nitrate salt cools down and solidifies at the outer surface. The solidified nitrate salt is removed from the surface of the drum by a stationary scraper, which enables the separation of the liquid and solid phase of the storage material. This results in a complete separation of the thermal power and the thermal capacity of the storage system. Numerical simulations indicate a surface-specific heat transfer density of up to 300 $KW \cdot m^{-2}$ when sodium nitrate is used as storage material and saturated steam is generated at a pressure of 8 bar. While the technology of the Rotating Drum Heat Exchanger has been experimentally proved for low-temperature application, a high-temperature prototype for high-pressure steam generation is currently under development. In addition to the current progress on the prototype, the presentation will describe and discuss a freely scalable design of the Rotating Drum Heat Exchanger for steam generation in the megawatt range. The heat exchanger is thereby integrated into an entire thermal energy storage system, which also enables the cogeneration of electricity and the flexibilization of current steam supply systems. The use of a phase change material also allows the efficient integration of high-temperature heat pumps.

Keywords

renewable process steam generation, thermal energy storage, phase change material, Rotating Drum Heat Exchanger, power to heat, cogeneration

Abstract Supplement

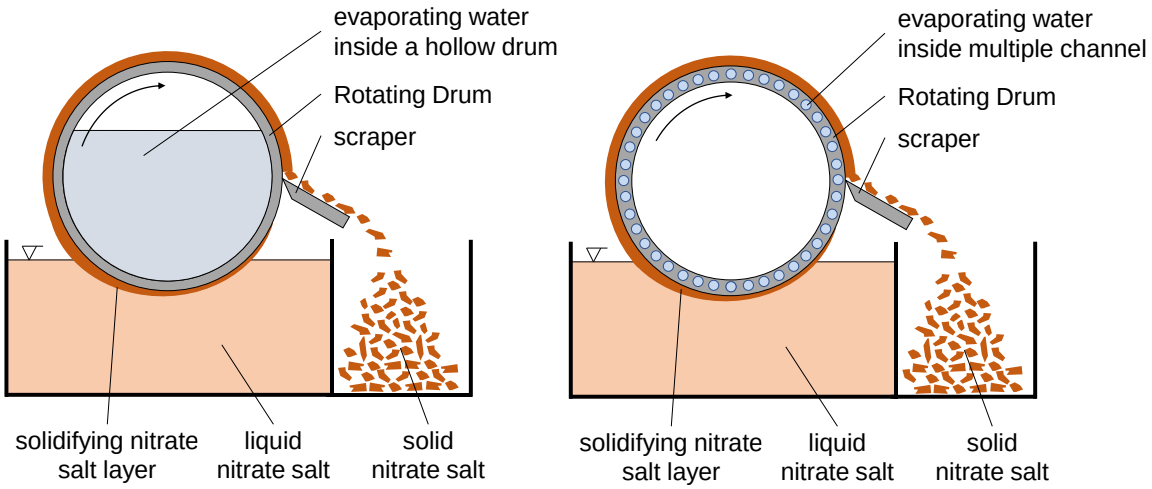

Figure 1: a) Illustration of a Rotating Drum Heat Exchanger using a hollow drum for the evaporation of water. The design is not freely scalable due to the increasing drum shell thickness with increased diameters to withstand the internal pressure. b) Illustration of a Rotating Drum Heat Exchanger using multiple channels inside the drum shell for the evaporation of water. The design is freely scalable since the outer diameter is not affecting the required shell thickness.

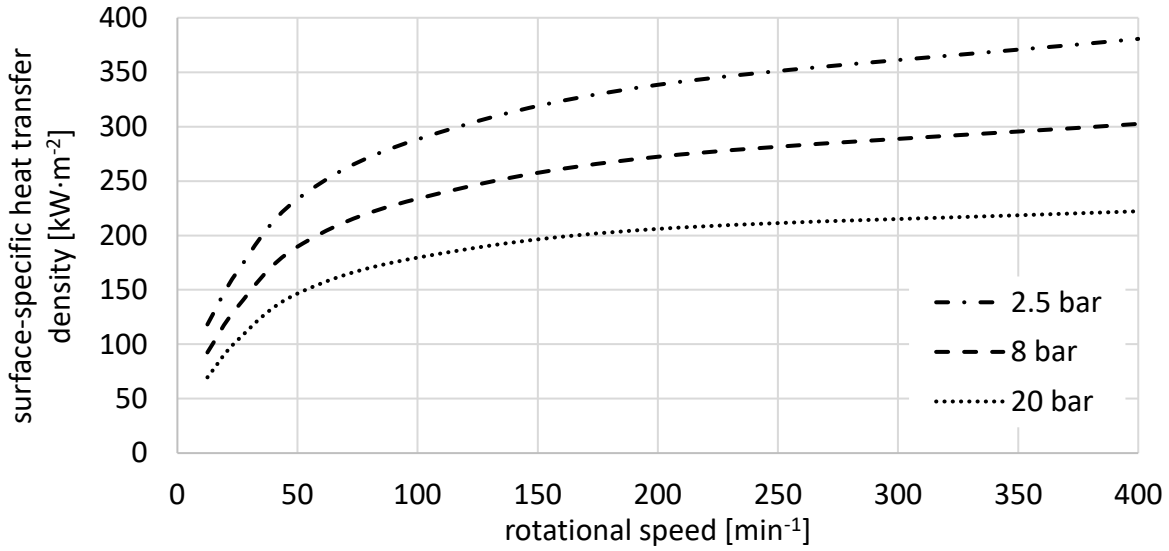

Figure 2: Surface-specific heat transfer density of the Rotating Drum Heat Exchanger as a function of the rotational speed when using sodium nitrate with a temperature of 350 °C as storage material. The heat transfer density is decreasing for higher pressures due to the lower temperature difference between the saturation temperature of the water and the melting point of the used storage material.

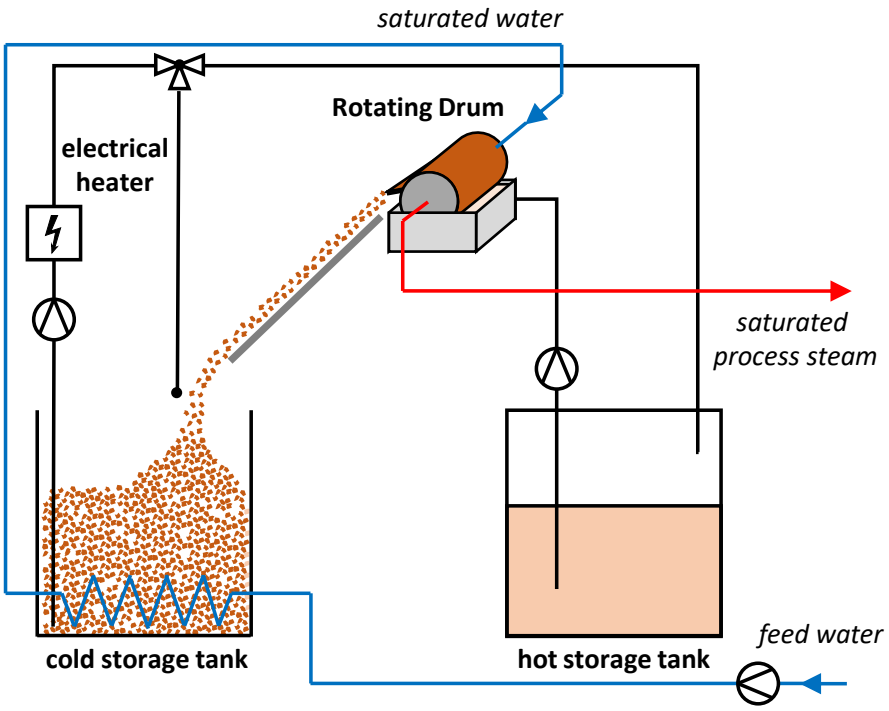

Figure 3: Thermal energy storage system for the provision of demand-orientated saturated process steam charged by fluctuating renewable electrical energy.

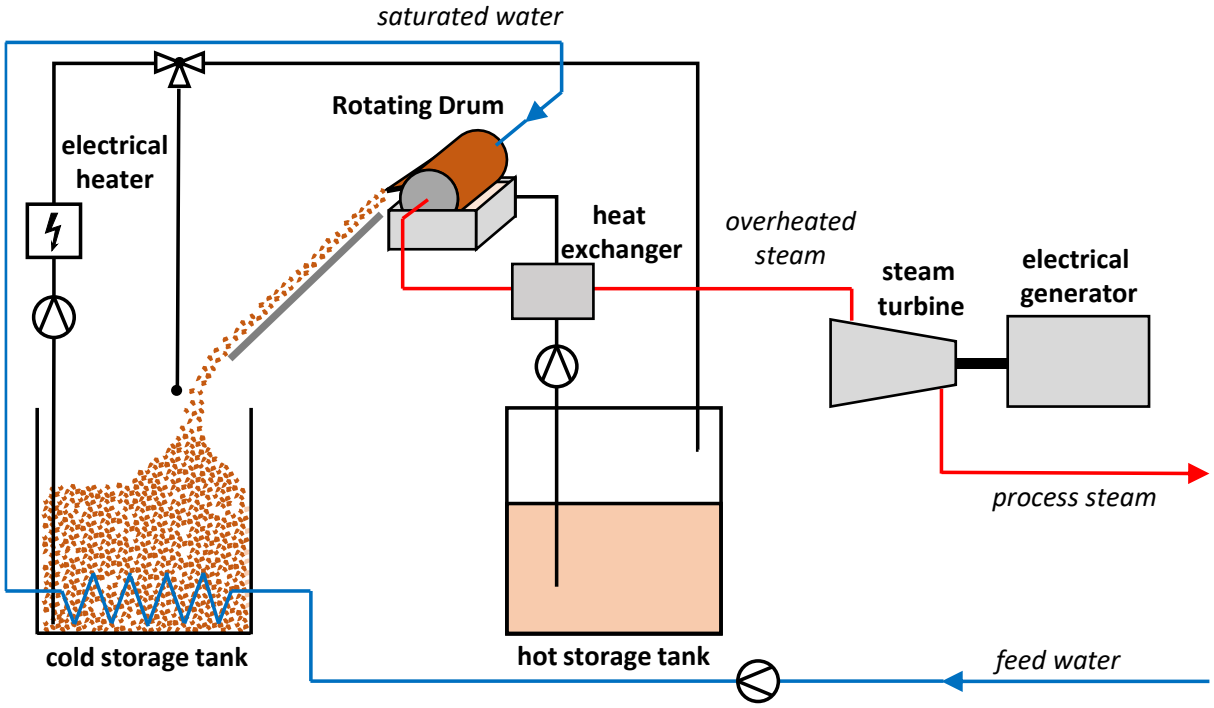

Figure 4: Thermal energy storage system for the cogeneration of process steam and electricity charged by fluctuating renewable electrical energy.